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PART XVIII

AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XVIII — DATA REPORT ON TEST SECTION 17

J. WATKINS and W. HILL, JR.

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION

TECHNICAL REPORT AFFDL-TR-66-43, PART XVIII

SEPTEMBER 1966

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**AIR FORCE FLIGHT DYNAMICS LABORATORY
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AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XVIII — DATA REPORT ON TEST SECTION 17

J. WATKINS and W. HILL, JR.

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FOREWORD

The investigation described herein constitutes one phase of studies conducted during 1964 and 1965 at the U. S. Army Engineer Waterways Experiment Station (WES) under U. S. Air Force Project No. 410-A, MIPR No. AS-4-177, "Development of Landing Gear Design Criteria for the CX-HLS Aircraft." (The CX-HLS is now designated C-5A.) This project was sponsored and directed by the Landing Gear Group, Air Force Flight Dynamics Laboratory, Research and Technology Division, Mr. R. J. Parker, Project Engineer.

These tests were conducted by personnel of the WES Flexible Pavement Branch, Soils Division, under the general supervision of Messrs. W. J. Turnbull, A. A. Maxwell, and R. G. Ahlvin, and the direct supervision of Mr. D. N. Brown. Other personnel actively engaged in this study were Messrs. C. D. Burns, D. M. Ladd, W. N. Brabston, J. E. Watkins, H. H. Ulery, Jr., A. J. Smith, Jr., and W. J. Hill, Jr. This report was prepared by Messrs. Watkins and Hill.

Directors of WES during the conduct of this investigation and preparation of this report were Col. Alex G. Sutton, Jr., CE, and Col. John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

Publication of this technical documentary report does not constitute Air Force approval of the report's findings or conclusions. It is published only for the exchange and stimulation of ideas.



KENNERLY H. DIGGES
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ABSTRACT

This data report describes work undertaken as part of an overall program to develop ground-flotation criteria for the C-5A aircraft. A test section was constructed to a width adequate for two test lanes. The test lanes were unsurfaced and each lane was divided into two items having different subgrade CBR values. Traffic was applied to both lanes using a 35,000-lb load with a single-wheel assembly. For one lane the wheel assembly consisted of a single 56x16, 38-ply aircraft tire and for the other lane a single 56x16, 24-ply aircraft tire was used. Tire inflation pressure was 100 psi for both assemblies.

This report presents the data collected during trafficking on soil strengths, surface deformations and deflections, and drawbar pull. The traffic-coverage level at which each test item was considered failed is also given.

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SUMMARY

Tests on Section 17 are one phase of a comprehensive research program to develop ground-flotation criteria for heavy cargo-type aircraft. Section 17 consisted of two similar unsurfaced test lanes, lanes 36 and 37, each of which was divided into two items having different subgrade CBR values (figure 9).

Traffic was applied to the two lanes using a 35,000-lb load on a single-wheel assembly. On lanes 36 and 37, the wheel assemblies consisted of a 56x16, 38-ply aircraft tire and a 56x16, 24-ply aircraft tire, respectively. Tire inflation pressure was 100 psi. Figure 10 gives pertinent tire-print dimensions and tire characteristics.

The lanes were trafficked to failure in accordance with the criteria designated in Part I of this report. Data were recorded throughout testing to give a behavior history of each item. Using the test criteria mentioned above, it was possible to directly compare the effects of trafficking with identical single-wheel assemblies having different ply tires. Basic performance data are summarized in the following paragraphs.

Lane 36

Item 1

The item was considered failed at 4 coverages due to rutting and excessive transverse differential deformations. The rated CBR was 6.7.

Item 2

The item was considered failed at 16 coverages due to rutting and excessive transverse differential deformations. The rated CBR was 9.2.

Lane 37

Item 1

The item was considered failed at 10 coverages due to rutting and excessive transverse differential deformations. The rated CBR was 6.7.

Item 2

The item was considered failed at 50 coverages due to excessive transverse differential deformations. The rated CBR was 11.

AIRCRAFT GROUND-FLOTATION INVESTIGATION

PART XVIII DATA REPORT ON TEST SECTION 17

SECTION I: INTRODUCTION

The investigation reported herein is one phase of a comprehensive research program being conducted at the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss., as part of U. S. Air Force Project 410-A, MIPR No. AS-4-177, to develop ground-flotation criteria for the C-5A, a heavy cargo-type aircraft. Specifically, the tests reported herein were conducted to determine the effect of tire ply rating of single-wheel landing-gear assemblies on unsurfaced soils under identical conditions of loading.

Prosecution of this investigation consisted of constructing two similar test lanes and subjecting them to traffic of 35,000-lb loads on single-wheel assemblies differing only in tire ply rating. This report presents a description of the test section and wheel assemblies, and gives results of traffic. Equipment used, types of data and method of recording them, and general test criteria are summarized in this part; more complete explanations and illustrations appear in Part I of this report.

SECTION II: DESCRIPTION OF TEST SECTION AND LOAD VEHICLE

Description of Test Section

Test Section 17 (figure 9) was constructed within a roofed area in order to allow control of the subgrade CBR (California Bearing Ratio) in the test items. Section 17 was located on the same site as prior Test Sections 14, 6, 4, and 2 in this series; the original construction of the site is described in Part III of this report. The underlying subgrade was undisturbed by prior tests on the site so that in construction of Section 17 only the upper 24 in. of soil was excavated. The surface exposed by excavation was scarified and recompacted before backfilling the area in four compacted lifts with a heavy clay soil (buckshot; classified as CH according to the Unified Soil Classification System, MIL-STD-619). The fill material used was a local clay with a plastic limit of 27, liquid limit of 58, and plasticity index of 31. Gradation and classification data for the subgrade material are given in Part I.

Two unsurfaced traffic lanes, each divided into two items, were constructed in the test section. Different subgrade strengths were obtained in the items (figure 9) by controlling the water content and compaction effort.

Load Vehicle

The load vehicle used for trafficking the test lanes in Section 17 is shown in figure 2. Load cart construction, details of linkage between the load compartment and prime mover, and method of applying load are explained in Part I. For trafficking lanes 36 and 37, single-wheel assemblies were used with a 35,000-lb load. A 56x16, 38-ply aircraft tire and a 56x16, 24-ply aircraft tire were used on lanes 36 and 37, respectively. Tire inflation pressure was 100 psi for both assemblies. Tire-print data and pertinent tire characteristics are given in figure 10.

SECTION III: APPLICATION OF TRAFFIC, FAILURE CRITERIA, AND DATA COLLECTED

Application of Traffic

Traffic was applied to the test lanes in a nonuniform pattern with intensity of traffic being varied within each lane to produce three zones of approximately 100, 80, and 20 percent traffic coverage. Traffic so distributed within a traffic lane simulates as nearly as possible the bell-shaped traffic distribution curve which results from the wander of aircraft from the lane center line. The coverage levels recorded in the tables and text of this report are the total number of coverages applied to the 100 percent coverage zone. The corresponding number of coverages applied to the outer traffic zones is proportional to the percentage factor for the respective zones as shown in figure 1.

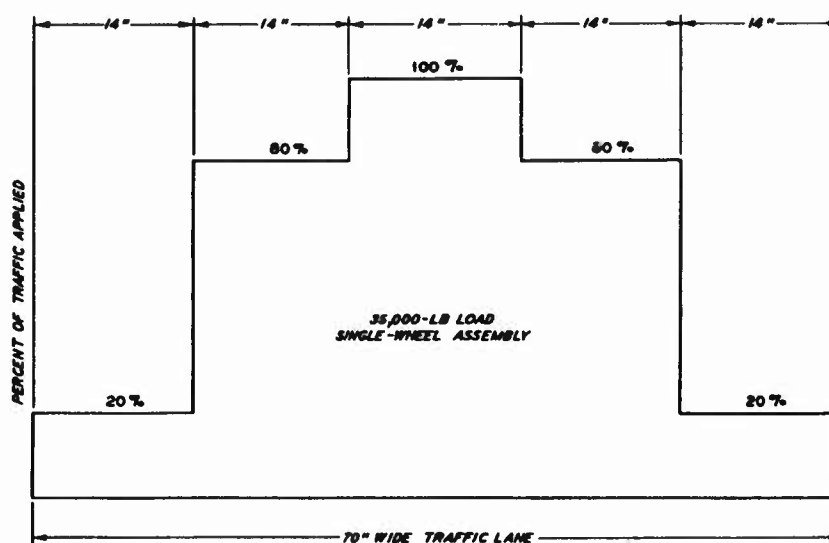


Figure 1. Traffic distribution pattern for lanes 36 and 37

Failure Criteria and Data Collected

Failure criteria used in this investigation and descriptive terms used in presentation and discussion of data in all reports in this series are presented in Part I. A general outline of types of data collected is given in the following paragraphs. Details on apparatus and procedure for obtaining specific measurements are given in Part I.

CBR, water content, and dry density

CBR, water content, and dry density of the subgrade were measured for each test item prior to application of traffic, at intermediate

coverage levels, and at failure. After traffic was concluded on an item, a measure of subgrade strength termed "rated CBR" was determined. Rated CBR is generally the average CBR value obtained from all the determinations made in the top 12 in. of soil during the test life of an item. In certain instances, extreme or irregular values may be ignored if the analyst decides that they are not properly representative.

Surface roughness, or differential deformation

Surface roughness, or differential deformation, measurements were made using a 10-ft straightedge at various traffic-coverage levels on all items. Rut depths were also measured.

Deformations

Deformations, defined as permanent cumulative surface changes in cross section or profile of an item, were charted by means of level readings at pertinent traffic-coverage levels.

Deflection

Deflection of the test surface under an individual static load of the tracking assembly was measured at various traffic-coverage levels. A pin and cap device was used to measure deflection directly beneath the load wheel. Both total and elastic (recoverable) deflections were measured.

Rolling resistance

Rolling resistance, or drawbar pull, measurements were performed with the load vehicle over each test item at designated coverage levels. Apparatus and procedure for determining drawbar pull values are illustrated and explained in Part I.

SECTION IV: BEHAVIOR OF ITEMS UNDER TRAFFIC AND TEST RESULTS

Lane 36

Behavior of items under traffic

Item 1. Item 1 prior to traffic is shown in figure 3. The surface of the subgrade deformed readily under traffic and at 4 coverages the item was considered failed due to rutting and excessive differential deformations (figure 4). The rated CBR of the item was 6.7.

Item 2. Item 2 prior to traffic is shown in figure 3. At 16 coverages the item was considered failed due to rutting and excessive differential deformations (figure 5). The rated CBR of the item was 9.2.

Test Results

Results of trafficking lane 36 are summarized in table 1. Soil test data are given in table 2.

Item 1. Item 1 was considered failed at 4 coverages. The following information was obtained from traffic tests on item 1.

- a. Roughness. Transverse and diagonal differential deformations and rut depths were about equal throughout trafficking (table 1), with each averaging 4.75 in. at failure. Longitudinal differential deformations were insignificant.
- b. Deformation. Average cross-section deformations at 4 coverages are shown in figure 11. Considerable soil upheaval above the original grade level is evident in the figure. Figure 12 shows a profile along the lane center line at 4 coverages, illustrating the uniform longitudinal subsidence.
- c. Deflection. The total and elastic subgrade deflections at 0 and 4 coverages are shown in table 1. Total deflection increased from 1.5 to 1.6 in. while elastic deflection increased from 0.5 to 1.0 in.
- d. Rolling resistance. Drawbar pull values at 0 and 4 coverages are shown in table 1. Peak drawbar pull increased with traffic from 3.7 to 5.0 kips while rolling drawbar pull increased only slightly from 2.4 to 2.8 kips.

Item 2. Item 2 was considered failed at 16 coverages. The following information was obtained from traffic tests on item 2.

- a. Roughness. Rut depths and differential deformations increased consistently with traffic (table 1). Transverse differential

deformation and rut depths averaged 3.84 in. at failure while average diagonal differential deformation was 3.97 in.

- b. Deformation. Average cross-section deformations at 4 and 16 coverages are shown in figure 11. Figure 12 shows a profile along the item center line at 4 and 16 coverages illustrating progressive subsidence of the subgrade along the entire item length as traffic continued.
- c. Deflection. Application of traffic produced no significant change in total and elastic subgrade deflections (table 1). Elastic deflection increased from 0.5 to 0.6 in. while total deflection was 0.8 in. before and after traffic with an intermediate measurement of 1.0 in. at 4 coverages.
- d. Rolling resistance. Peak and rolling drawbar pull increased with traffic, measuring 3.0 and 2.1 kips, respectively, at failure.

Lane 37

Behavior of items under traffic

Item 1. Item 1 prior to traffic is shown in figure 6. At 10 coverages the item was considered failed due to rutting and excessive differential deformations (figure 7). The rated CBR of the item was 6.7.

Item 2. Item 2 prior to traffic is shown in figure 6. At 50 coverages the item was considered failed due to rutting and excessive differential deformations (figure 8). The rated CBR of the item was 11.

Test results

Results of trafficking lane 37 are summarized in table 1. Soil test data are given in table 2.

Item 1. Item 1 was considered failed at 10 coverages. The following information was obtained from traffic tests on item 1.

- a. Roughness. Differential deformations and rut depths developed consistently with traffic (table 1). Transverse and diagonal differential deformations and rut depths each averaged 4.63 in. at failure.
- b. Deformation. The average cross-section deformation at 10 coverages is shown in figure 11. The longitudinal center-line rut indicated in the cross-section plot is the area represented in the center-line profile shown in figure 12 where general

subsidence along the lane is indicated.

- c. Deflection. Total subgrade deflection (0.9 in.) was unchanged with traffic while elastic subgrade deflection increased from 0.4 to 0.7 in. (table 1).
- d. Rolling resistance. Drawbar pull values at 0 and 10 coverages are shown in table 1. Peak drawbar pull increased from 2.0 to 4.3 kips while rolling drawbar pull increased from 1.5 to 3.5 kips.

Item 2. Item 2 was considered failed at 50 coverages. The following information was obtained from traffic tests on item 2.

- a. Roughness. Average transverse differential deformation was 3.56 in. at failure. Average diagonal differential deformation and average rut depth were both 3.31 in. (table 1).
- b. Deformation. Average cross-section deformations at 10 and 50 coverages are shown in figure 11. Severity of rutting increased considerably between the two coverage levels. Figure 12 shows center-line profiles at 10 and 50 coverages, and indicates that longitudinal subsidence increased consistently with traffic.
- c. Deflection. Total subgrade deflection increased from 0.4 to 0.7 in. with traffic while elastic subgrade deflection increased from 0.1 to 0.2 in. (table 1).
- d. Rolling resistance. Drawbar pull values at 0, 10, and 50 coverages are shown in table 1. Peak drawbar pull increased from 1.5 to 2.6 kips while rolling drawbar pull increased from 1.2 to 2.0 kips.

SECTION V: PRINCIPAL FINDINGS

From the foregoing discussion, the principal findings relating test load, wheel assembly, tire inflation pressure, subgrade CBR, and traffic coverages are as follows:

<u>Load, Wheel Assembly, and Tire Pressure</u>	<u>Test Item</u>	<u>Rated Subgrade CBR*</u>	<u>Coverages at Failure</u>
<u>Lane 36</u>			
35,000-lb load; single-wheel assembly; 56x16, 38-ply tire at 100-psi inflation pressure	1	6.7	4
	2	9.2	16
<u>Lane 37</u>			
35,000-lb load; single-wheel assembly; 56x16, 24-ply tire at 100-psi inflation pressure	1	6.7	10
	2	11	50

* All test items were unsurfaced.

TABLE 1

SUMMARY OF TRAFFIC DATA, TEST SECTION 17

Test Item	Cover- ages	Rated CBR	Differential Deformation (in.)				Rut Depths (in.)		Drawbar Pull (kips)	Subgrade Deflection at Center		Remarks		
			Transverse		Diagonal		Max	Avg		Line of Wheel Assembly (in.)	Total Elastic			
			Max	Avg	Max	Avg			Peak		Roll- ing		Total Elastic	
Lane 36														
1 Unsurfaced	0	↑	--	--	--	--	--	--	3.7	2.4	1.5	0.5	Item failed at 4 coverages	
	2	6.7	4.63	4.22	4.75	4.28	4.63	4.22	--	--	--	--		
	4	↑	6.25	4.75	6.38	4.75	6.25	4.75	5.0	2.8	1.6	1.0		
2 Unsurfaced	0	↑	--	--	--	--	--	--	2.3	1.5	0.8	0.5	Item failed at 16 coverages	
	2	9.2	2.0	1.91	2.0	1.83	2.0	1.91	--	--	--	--		
	4	↓	3.0	2.31	2.5	2.25	3.0	2.31	2.4	2.0	1.0	0.6		
1 Unsurfaced	16	↓	4.0	3.84	4.5	3.97	4.0	3.84	3.0	2.1	0.8	0.6		
	Lane 37													
	0	↑	--	--	--	--	--	--	2.0	1.5	0.9	0.4	Item failed at 10 coverages	
2	6.7	1.75	1.28	--	--	--	1.75	1.28	--	--	--	--		
10	↑	5.00	4.63	5.00	4.63	5.00	4.63	4.3	3.5	0.9	0.7			
2 Unsurfaced	0	↑	--	--	--	--	--	--	1.5	1.2	0.4	0.1	Item failed at 50 coverages	
	2	11.0	0.50	0.44	--	--	--	0.50	0.44	--	--	--		
	10	↓	1.38	1.06	1.38	1.00	1.38	1.00	1.8	1.5	0.4	0.1		
30	↓	2.88	2.28	2.63	2.19	2.88	2.28	--	--	--	--	--		
	50	↓	4.50	3.56	4.00	3.31	4.00	3.31	2.6	2.0	0.7	0.2		

Note: A 35,000-lb load on a single-wheel assembly was used for trafficking. On lane 36 a 56x16, 38-ply tire was used and on lane 37 a 56x16, 24-ply tire was used. Tire inflation pressure was 100 psi.

TABLE 2
SUMMARY OF CBR, DENSITY, AND WATER CONTENT DATA, TEST SECTION 17

Test Item*	Coverages	Depth (in.)	CBR	Water Content (%)	Dry Density (lb/cu ft)	Remarks		
Lane 36								
1	0	0	6	24.7	98.1	Item failed at 4 coverages		
		6	7	23.6	97.9			
		12	7	23.3	100.0			
	0	0	6	23.5	100.4			
		6	7	23.8	99.4			
		12	7	23.1	99.3			
	4	0	6	23.9	99.7			
		6	7	22.3	101.2			
		12	7	25.2	97.2			
2	0	0	10	22.2	102.6	Item failed at 16 coverages		
		6	9	24.7	98.1			
		12	10	22.8	101.3			
	0	0	10	21.4	102.6			
		6	9	22.2	100.9			
		12	10	21.4	101.7			
	16	0	7	22.7	100.9			
		6	8	22.1	102.6			
		12	11	20.9	103.6			
Lane 37								
1	0	0	6	24.7	98.1	Item failed at 10 coverages		
		6	7	23.6	97.9			
		12	7	23.3	100.0			
	0	0	6	23.5	100.4			
		6	7	23.8	99.4			
		12	7	23.1	99.3			
	10	0	7	23.4	99.6			
		6	6	23.9	99.1			
		12	7	24.2	98.8			
2	0	0	10	22.2	102.6	Item failed at 50 coverages		
		6	9	24.7	98.1			
		12	10	22.8	101.3			
	0	0	10	21.4	102.6			
		6	9	22.2	100.9			
		12	10	21.4	101.7			
	50	0	11	21.8	102.3			
		6	9	21.2	102.7			
		12	14	21.0	104.1			

Note: All items were unsurfaced.

* Subgrade material was a heavy clay (buckshot; classified as CH) in all items.



Figure 2. Load vehicle used in trafficking Test Section 17



Figure 3. Lane 36, items 1 and 2, prior to traffic

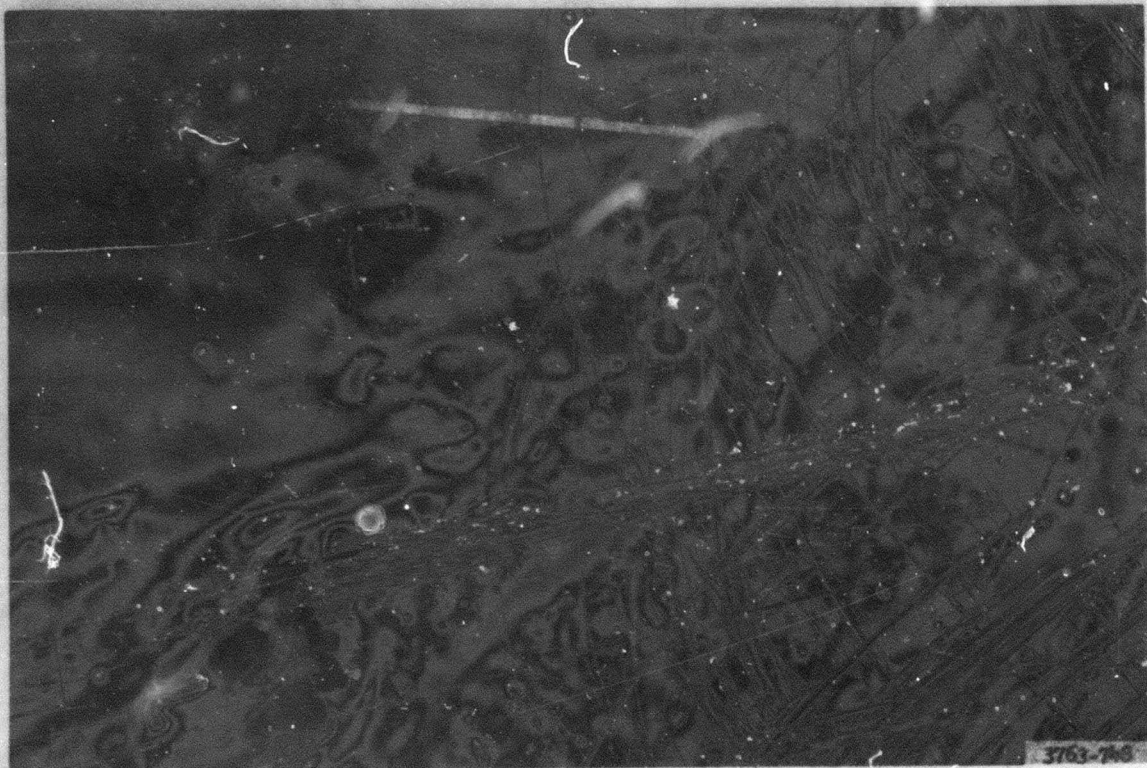


Figure 4. Lane 36, item 1. Transverse straightedge shows roughness at 4 coverages (failure)

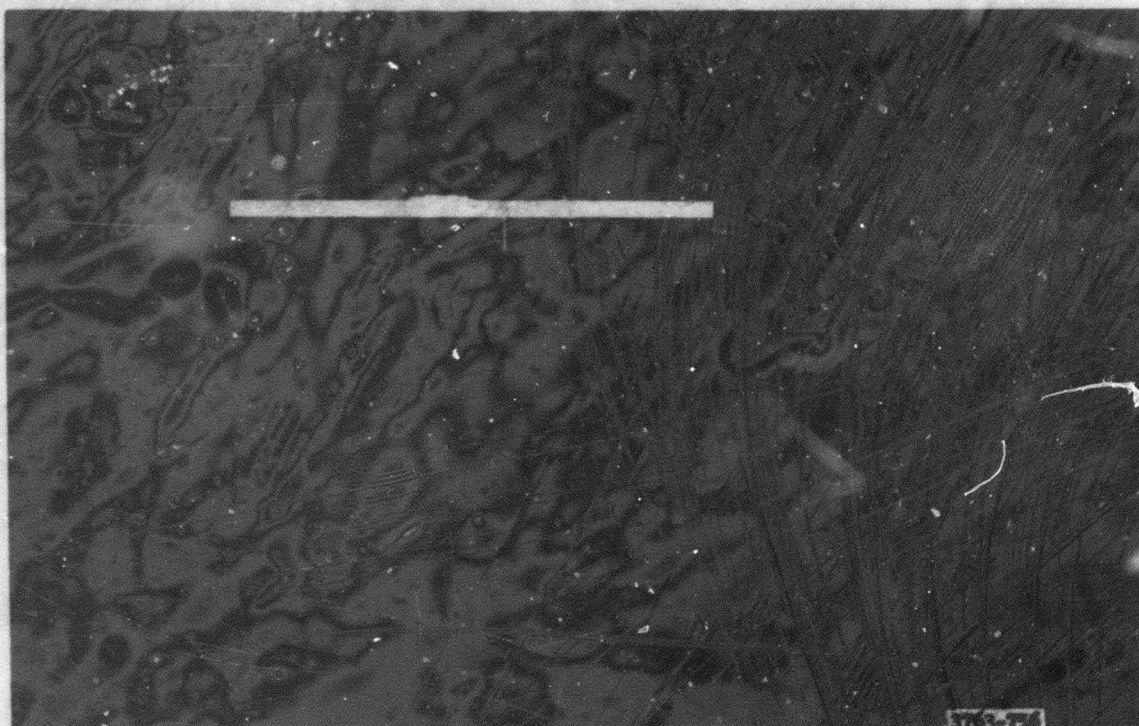


Figure 5. Lane 36, item 2. Transverse straightedge shows roughness at 16 coverages (failure)

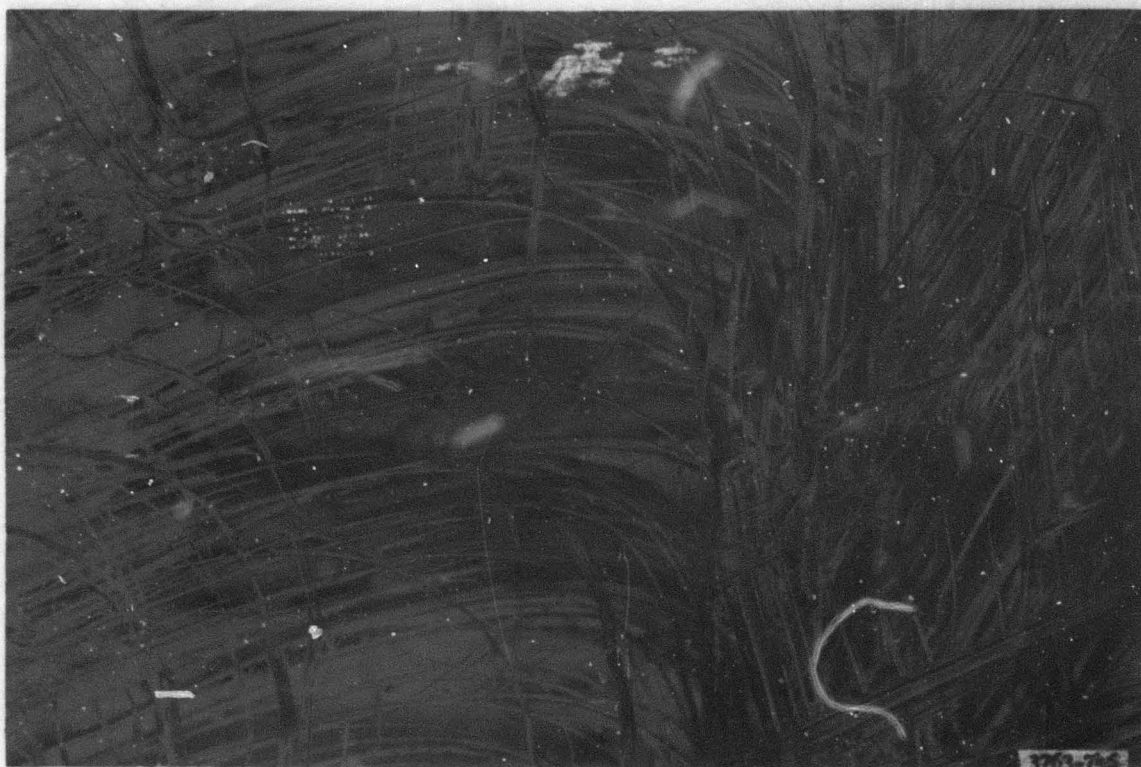


Figure 6. Lane 37, items 1 and 2, prior to traffic

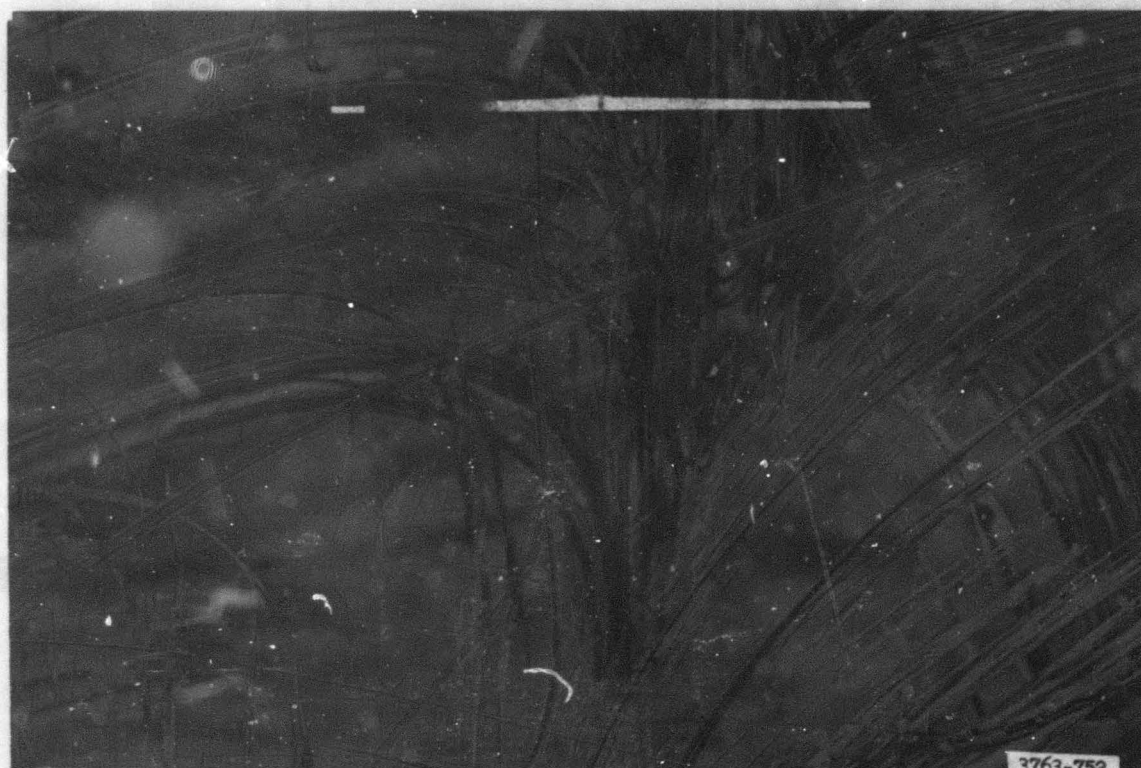


Figure 7. Lane 37, item 1. Transverse straightedge shows roughness at 10 coverages (failure)

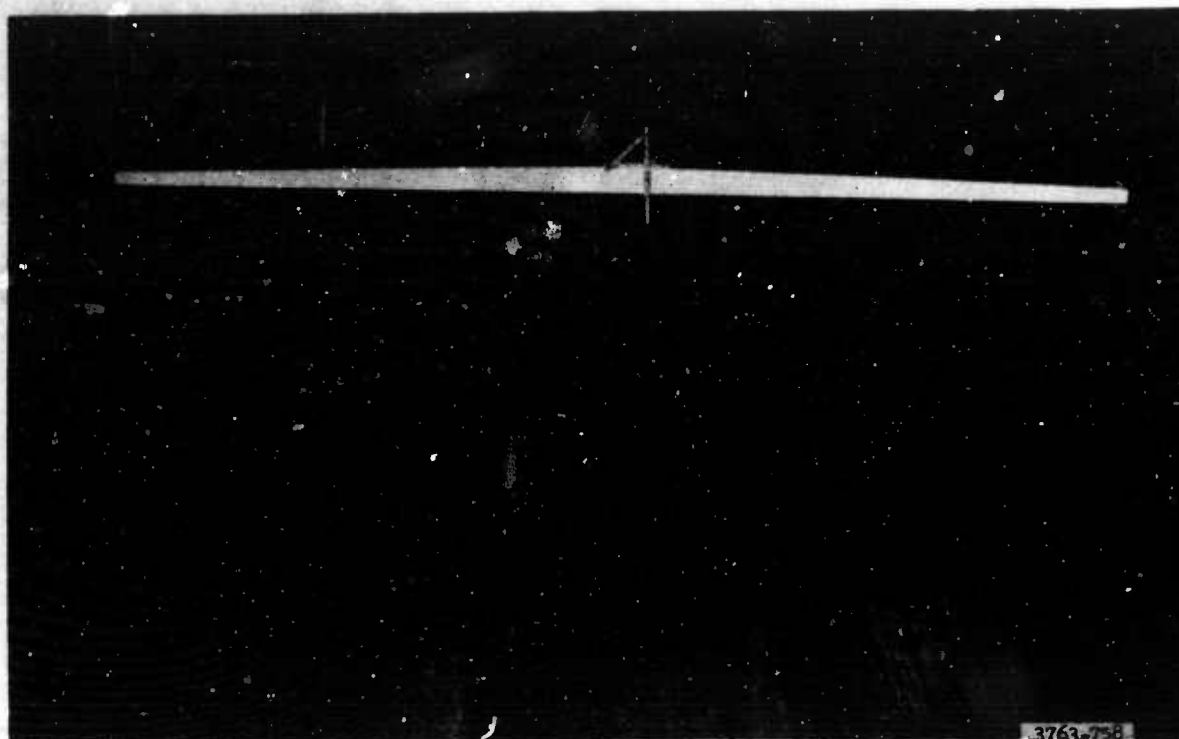
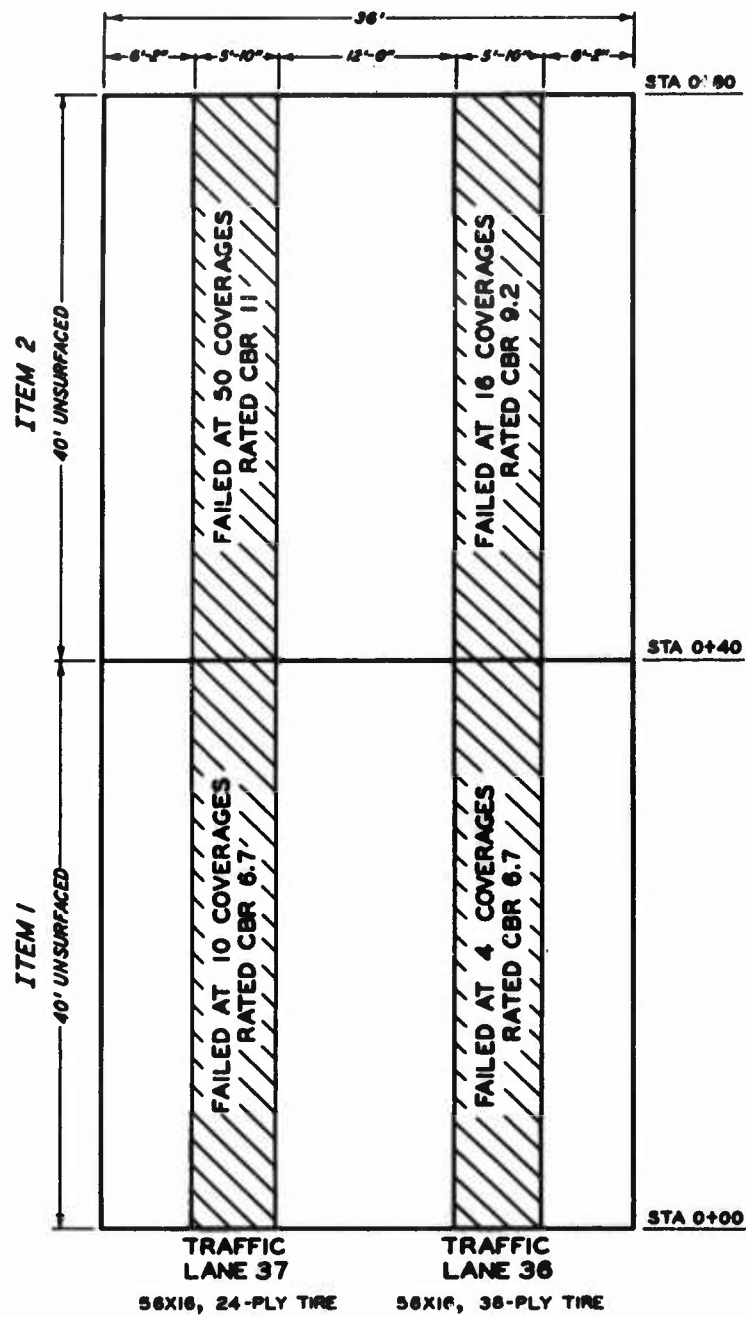
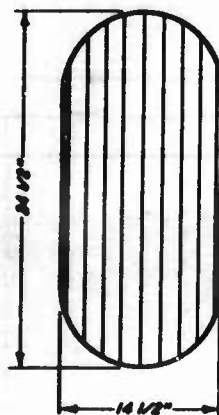


Figure 8. Lane 37, item 2. Transverse straightedge shows roughness at 50 coverages (failure)



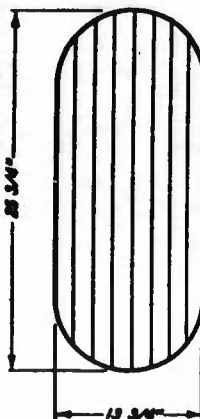
LAYOUT OF
TEST SECTION 17 AND
SUMMARY OF TEST RESULTS
35,000-LB, SINGLE-WHEEL LOAD
100-PSI INFLATION PRESSURE

Figure 9



TIRE SIZE	56X16
NO. OF PLYS	38
CONTACT AREA, SQ IN.	312
CONTACT PRESSURE, PSI	112
INFLATION PRESSURE, PSI	100
DEFLECTION, %	37
GROSS ASSEMBLY LOAD, KIPS	35

LANE 36



TIRE SIZE	56X16
NO. OF PLYS	24
CONTACT AREA, SQ IN.	318
CONTACT PRESSURE, PSI	109
INFLATION PRESSURE, PSI	100
DEFLECTION, %	43
GROSS ASSEMBLY LOAD, KIPS	35

LANE 37

TIRE-PRINT DIMENSIONS AND TIRE CHARACTERISTICS

TEST SECTION 17
LANES 36 AND 37

Figure 10

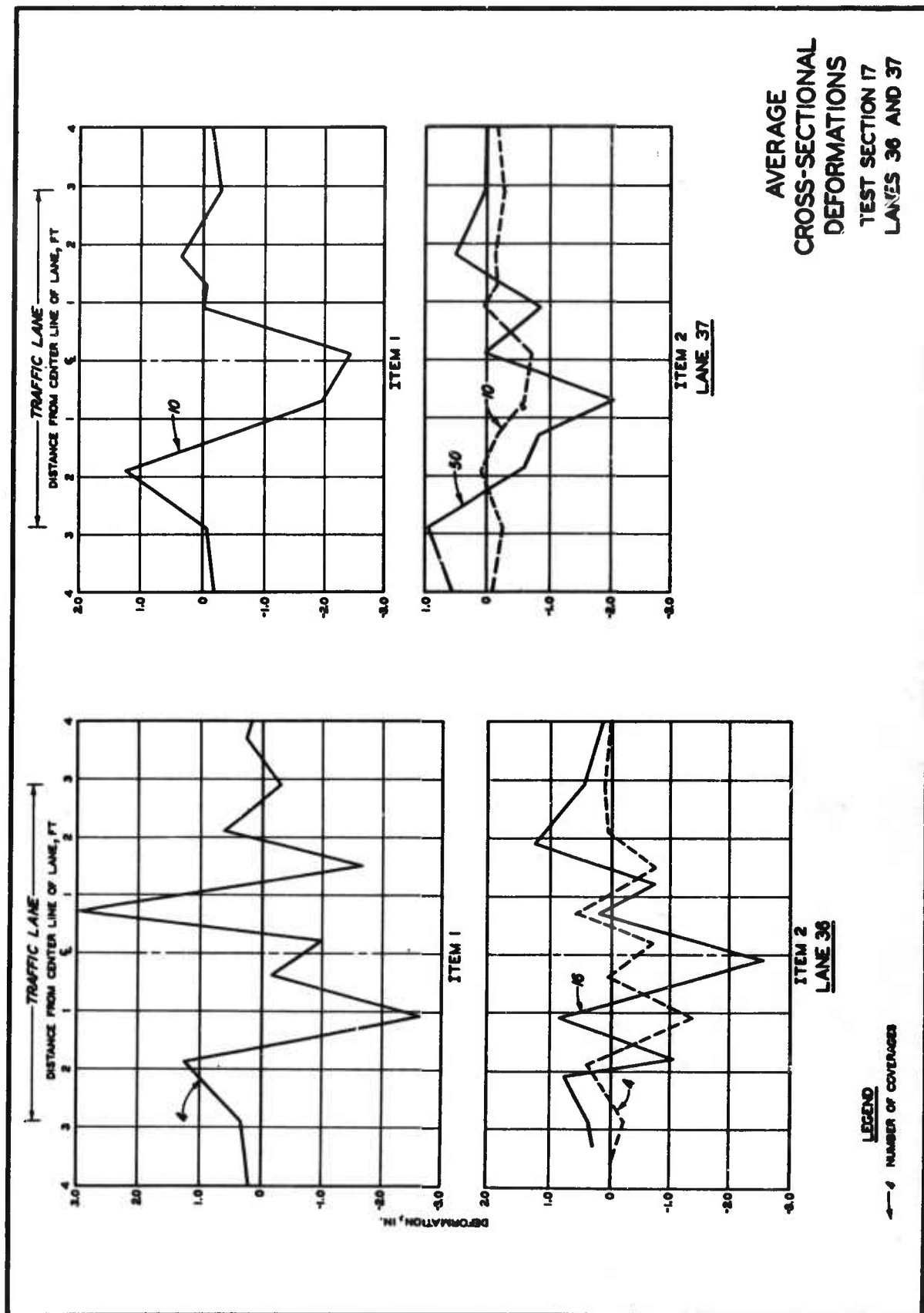


Figure 11

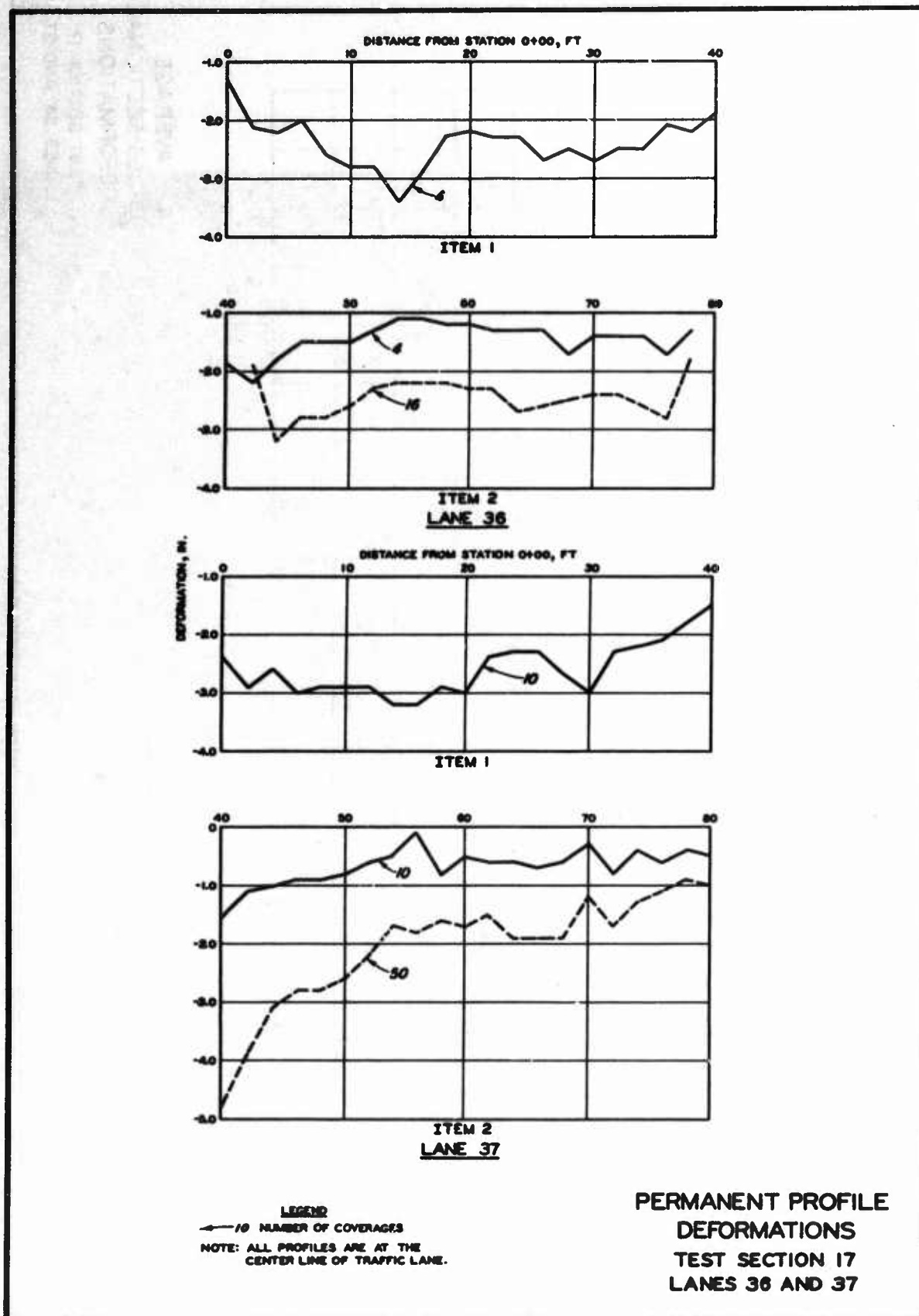


Figure 12

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13. ABSTRACT This data report describes the results of work undertaken as part of an overall program to develop ground-flotation criteria for the C-5A aircraft.		

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Aircraft Ground Flotation Rolling Resistance Rear Area Airfields Support Area Airfields Forward Area Airfields Vehicle Mobility						

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